Static and Acoustic Characteristics of Various Compressive Strength Concrete Composites

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ABSTRACT:*Steel fiber reinforced concrete (SFRC) was developed in volume fraction up to 1.5%. The static and acoustic behaviors of these composites under various loads were investigated. The mechanical properties such as: compressive and flexural strength were enhanced up by reinforcing with steel fiber. Moreover sonic parameters of these composites such as pulse velocity weredetermined usingultra sonic technique. The results showed that pulse velocity inversely proportional to subjected load, and enhanced with curing age.*
Keywords:*Acoustic, Characteristics, Concrete Composites, Compressive Strength, Static*

INTRODUCTION

Concrete has good engineering properties and appropriate cost, therefore it is used by far for construction material, but there is some obstacles to use the concrete material as listed below: It is weak in resisting tensile forces, low ductility (brittleness), low strain capacity, very little fatigue life, andlimited resistance to cracking [1]. The weakness of concrete can be removed by inclusion variety of innovative materials such as fibers (steel, polypropylene, glass, and carbon) due to the numerous advantages over ordinary plain concrete and increased in the mechanical behavior of tension weak concrete [2]. Fibers used to control the cracking by applying pinching forces at the crack tips, thus delaying their propagation across the matrix and creating a slow crack propagation stage [3].Steel fibers are sufficiently strong, fast and perfect mixable fibers, sufficiently bonded to material against impact forces , permit the fiber reinforced concrete(FRC) to carry significant stresses over a relatively large strain capacity in the post-cracking stage, appropriate cost, and improving the toughness characteristics of hardened concrete [4,5] .In producing steel fiber reinforced concrete fiber were used with volume fraction percent(0.5% to 1.5%) as the addition of fiber may reduce the workability of the mix and will tend to balling or mat which will be extremely difficult to separate by vibration.. Aspect ratio is the ratio of fiber length over the diameter. Aspect ratio of steel fiber greater than 100 is not recommended andthe normal range of aspect ratio for steel fiber is from 20 to 100 because it will formation of mat in the mix, reduce workability, tend to ball in the mix [6].The most common applications of SFRC are tunnel linings, pavements, slabs, shotcrete and now shotcrete also containing silica fume, airport pavements, and bridge deck slab repairs [4].

Experimental Work

Materials:

A-Cement: Type (1) Ordinary Portland Cement (OPC) manufactured by sulaymaniyah cement factory was used in all mixes throughout this investigation .The chemical composition and physical properties of the cement performed by National Center for Construction Laboratories as shown in tables(1), and (2). Test results show that the cement conforms to the Iraqi standard specification (I.Q.S) No.5, 1984 [7].

Table (1):Chemical composition and main compounds of the cement.

NO	Compound composition	Chemical composition	%By weight	Limit of Iraqi specifications No.5,1984
1	Lime	CaO	63.39	-
2	Silica	SiO_2	20.07	-
3	Alumina	Al_2O_3	4.77	-
4	Iron oxide	Fe_2O_3	5.88	-
5	Sulfite	SO_3	2.3	2.8 (Max)
6	Magnesia	MgO	4.66	5.0 (Max)
7	Loss on ignition	L.O.I	2.08	4.0 (Max)
9	Insoluble residue	I.R	0.86	1.5 (Max)
10	Lime saturation factor	L.S.F	0.98	0.66 - 1.02 (Max)
11	Tricalcium silicate	C_3S	-	-

12	Dicalcium silicate	C_2S	-	-
13	Tricalcium aluminate	C_3A	-	5.0 (Min)
14	Tetra calcium alumina ferrite	C_4AF	-	-

Table (2): Physical properties of Portland cement.

Physical properties	Test results	Limit of Iraqi specifications No.5,1984
Specific surface area (Blaine method) m^2/kg	356	230 (Min)
Setting time (vicats method) Initial setting, hrs:min Final setting, hrs:min	 2:15 5:00	 1 hr. (Min) 10 hr. (Max)
Compressive strength of mortar, MPa 3-day 7-day	 20.0 30.0	 15.0 (Min) 23.0 (Min)
Autoclave expansion, %	-	-

B-1 Fine aggregate: The fine aggregate used inconcretemix for this investigation is brought from Al-Ukadhir region, and tested to determine the grading and other physical properties. Table (3) shows the sieve analysis of fine aggregate. Results indicate that the fine aggregate grading and sulfate content were within the requirement of Iraqi specification (I.O.S) No.45, 1984 [8].The specific gravity, sulfate content of fine aggregate are (2.6), and (0.137%) respectively.

Table (3): Grading of fine aggregate.

Sieve size (mm)	Cumulative passing (%)	Limit of Iraqi specification No.45,1984
4.75	95	90-100
2.36	79	75-100
1.18	62	55-90
0.06	45	35-59
0.30	19	8-30
0.15	5	0-10

B-2 Coarse aggregate: Crushed gravel brought from Niba'ee region maximum size 9.5mm was used for all mixes. The selection of this size was based on the consideration of getting acceptable workability and uniform dispersion of fibers in the composite [9]. Table (4) shows the grading of coarse aggregate used and it conforms of the Iraqi specification No.45, 1984. The specific gravity and sulfate content of coarse aggregate are (2.6), and (0.057%) respectively.

Table (4): Grading of coarse aggregate.

Sieve size (mm)	Percentage passing (%)	Limit of Iraqi specification No.45,1984
37.5	100	100
20	95	95-100
14	65	-
10	38	30-60
5	2	0-10

C- Mixing water: Ordinary tap water was used for all mixes, and curing. It is clear from harmful substances like oil and organic material.

D- **Reducing admixture (Superplasticizer):** This is known commercially as SODAMCO (CF555) a superplasticizer type sulphonated melamine formaldehyde condensate was used in this work, and its typical properties are listed in table (5).This special

formulation enables to retain concrete workability for longer time at low (w/c) at hot weather conditions. It can maintain good mixture appearance without segregation or bleeding.

Table (5): Typical properties of SODAMCO (CF555)*.

Appearance	Liquid
Color	Brown
Specific gravity at 20˚C	1.205-1.225(1.24±0.03)
Chloride content	Zero
Air entrainment	Up to 3% depending on dosage rate and concrete proportioning

* From manufacture catalogue.

E- Steel fiber: In this work hooked end steel fibers are used with length (30mm), diameter (0.6mm),aspect ratio(50), density(7.86kg/m³),and young's modulus of steel fibers(2×10^5MPa).

Mix design

The mixes of concrete are designed according to British Standard method B.S 1881:part2 [10].All mixes were designed to have 28 days of curing. After many trials two reference mix proportion were used in this study (low, and high compressive strength concrete), (LCSC, and HCSC) (C_{20}, and C_{40})MPa of compressive strength as presented in tables (6), and (7) respectively.

Table (6): Mix proportion of 20MPa compressive strengthconcrete (LCSC).

Material	Calculated quantity
Cement	380 kg
Course aggregate	690 kg
Fine aggregate	1171kg
Water	190 Liters

Table (7): Mix proportion of 40MPa compressive strengthconcrete (HCSC).

Material	Calculated quantity
Cement	482 kg
Course aggregate	592 kg
Fine aggregate	1151kg
Water	164 Liters
Superplistizer	1 %

At first the dry constituents (cement, sand and aggregate) are initially mixed for (one-three) minutes in a rotarymixer of $0.1m^3$ capacity. Then the required amount ofwater/admixture are added, and the whole mix constituents are mixed for few minutes, and then fibers are added slowly, and operation of rotary mixer for (one) minute only.
The mixes are poured into the moulds in two or three layers; each layer was vibrated by vibrating table. The specimens were then covered with nylon sheets to prevent evaporation of mixing water from concrete, and they were left for about 24 hours in the laboratory. After that all the specimens were demoded, and they were cured in water for testing at the ages 28 days.

Testing Methods

Cube with dimensions (100x100x100mm) and prism (100x100x400mm) dimensions tested at age28 days to calculate **(density, compressive strength, flexural strength, and ultrasonic pulse velocity under static load**).

A-Density test: Cubewith dimensions (100x100x100mm) used to determine density by dividing the unit mass of the cube by the unit volume:

Density $\rho = m/v$
Where:
ρ= Density of specimen concrete (g/cm^3).
m =Mass of specimen concrete (g).
v =Volume of specimen concrete (cm^3).

B-Compressive strengthtest: Cubewith dimensions (100x100x100mm) used to determine compressive strength by stress generated from the result of compression load per area of specimen surface according to B.S 1881: Part 116 [11]:

Compressive strength (MPa) = Load (N) / Area (mm^2)

C- Flexural strengthtest: Prisms with dimensions (100x100x400 mm) tested according toASTM C1609 [12] with a constant rate of loading about 0.015MPa/sec:

$$Fr = PL / bd^2$$

Where:
Fr = Flexural strength or modulus of rupture, (MPa).
P =Maximum applied load, (N).
L = Span length of specimen, (mm).
b =Average width of specimen aligned with fracture line, (mm).
d =Average depth of specimen aligned with fracture line, (mm).

D-Ultrasonic pulse velocity under static loadtest:Cubes with dimension (100×100×100mm) were placed in the 2000 kN machine, of capacity at loading rate 15 MPa/min under load control and checked (ultrasonic pulse velocity) at each load until the occurrence of the failure of sample. The ultrasonic pulse velocity test was determined according to B.S.1881: part 203.
The time the pulses take to travel through concrete is recorded. Then, the pulse velocity is calculated as:

$$V = L/T$$

Where:
V = Pulse velocity (m/s).
L = Length (m).
T =Effective time (s).

Results and discussion

A-Density test: Figure (1) shows the behavior of the density of SFRC as a function of volume fractionpercent, the density of concrete was clearly enhanced up on the inclusion of steel fiber. Higher density of steel would most definitely enhanced the density of the composite.

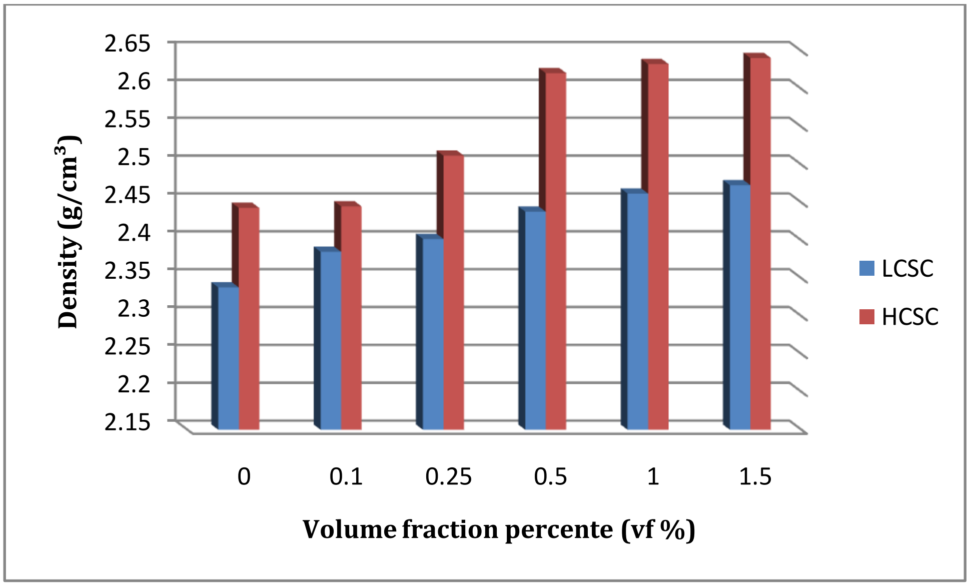

Fig. (1): Variation of density of (low and high) compressive strength concrete composite with volume fraction percent.

B-Compressive strength test: From figure (2)the compressive strength of LCSC composite increase from (9.3 to 44.7 %), andfor HCSCcomposite increase from (11 to 51 %) as well with addition of SF up to1.5 %. The addition of steel fiber enhanced the compressivestrength of concrete composite in linear manner due to strong bonds with matrix which maintain its mechanical strength.

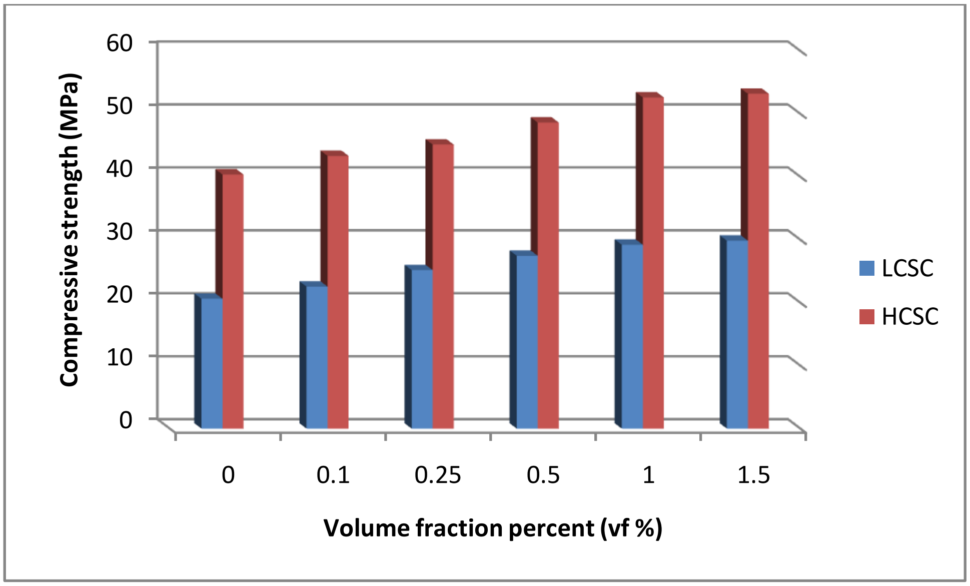

Fig (2): Variation of compressive strength of (low and high) compressive strength concrete composite with volume fractionpercent.

C-Flexural strength test: It is observed from figure (3) the flexural strength of LCSCcomposite increase from (7.01 to 52.87 %) and for HCSCcomposite increase from (6.10 to 63.94 %)with addition of SF up to 1.5 %. The attributed to superior bonding of steel with concrete matrix.

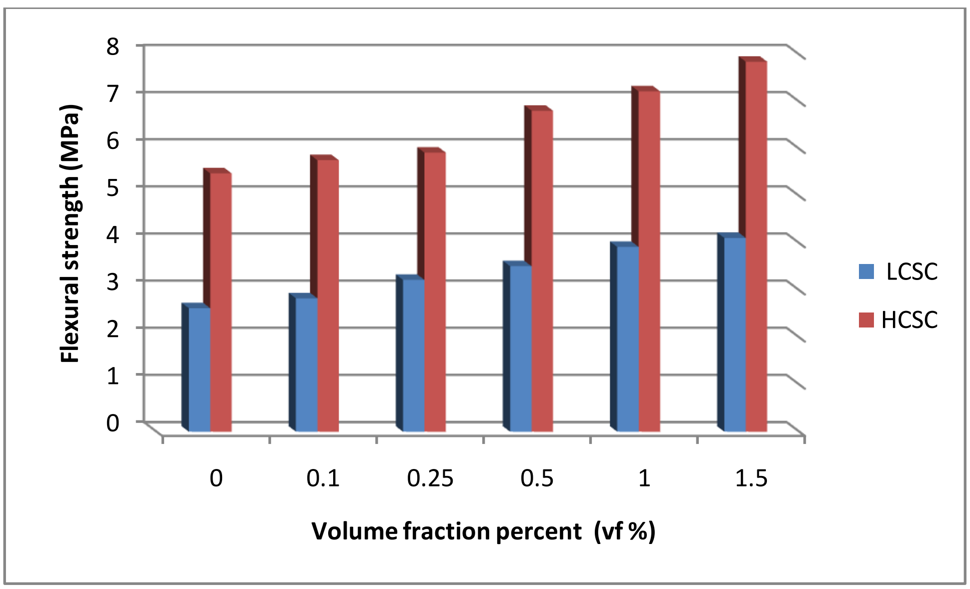

Fig. (3): Variation of flexural strength of (low and high) compressive strengthconcrete composite with volume fractionpercent.

D-Ultrasonic pulse velocity under static load test: It is observed from figures (4) and (5);the pulse velocity (V_P) and strength of concrete composites enhanced respectively, withvolume fraction percent for SFRC. Both the V_P and strength of concrete compositesincreasedwith increasescuring age, due to increase density of composites. The increasing of subjected static load leads to apparent decrease in the ultrasonic pulse velocity (V_P), this decrease was more in case of LCSC composites, because these compositeshave lower density than HCSC composites, and this causes to faster cracks propagation of LCSC composites compared to the HCSC composites.

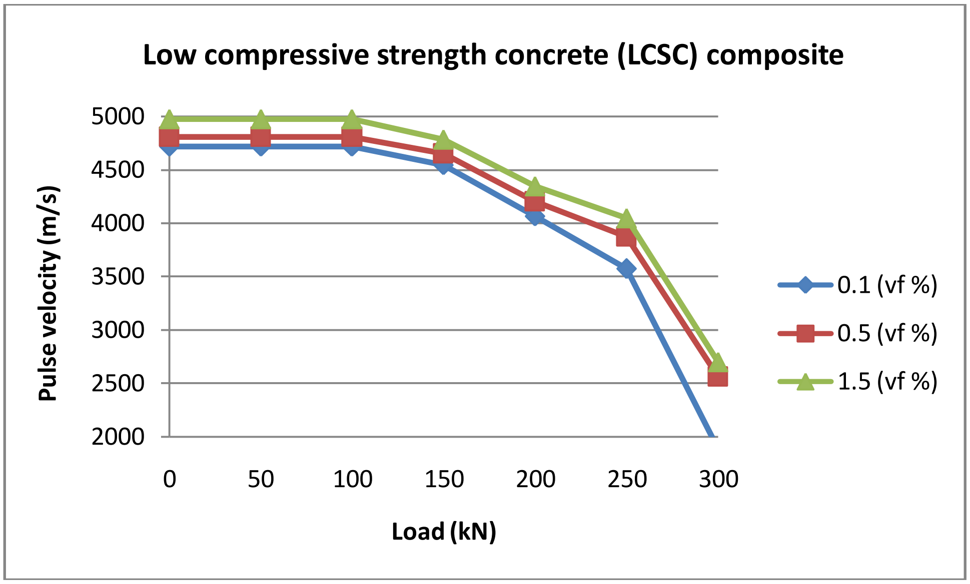

Fig. (4):Variation of pulse velocity under static load of low compressive strength concrete composite withvolume fractionpercent.

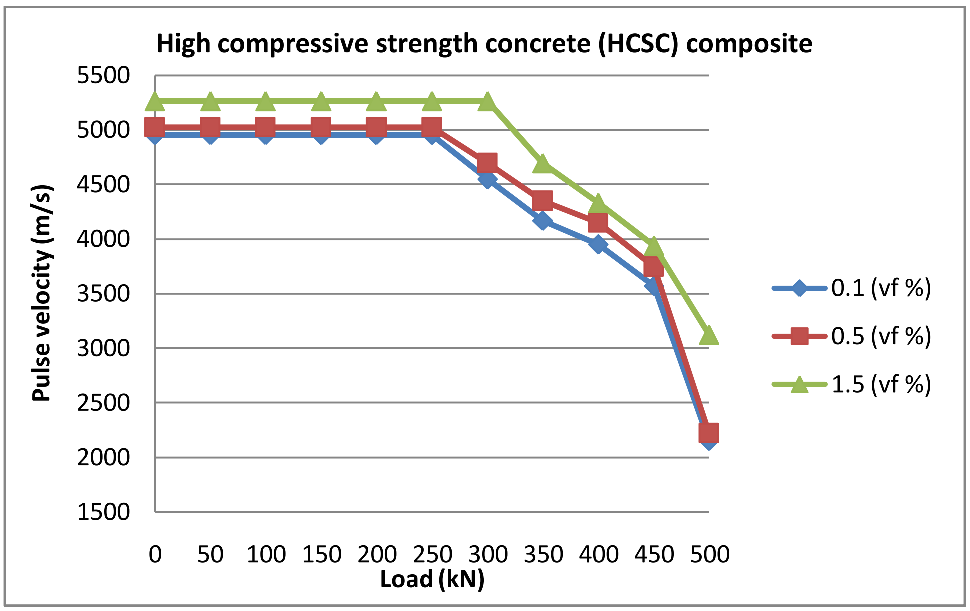

Fig. (5):Variation of pulse velocity under static load of high compressive strength concrete composite with volume fraction percent.

Conclusion

1. Density of LCSC and for HCSC compositesenhanced up with increased volume fraction percent of steel fiber.
2. Compressive strength of LCSC and for HCSC composites were increasing from (9.3 to 44.7 %), and from (11 to 51 %) respectively with increasing additionof SF up to volume fraction percent of 1.5%.
3. Flexural strength of LCSCcompositeincrease from (7.01 to 52.87 %) and for HCSC composite increase from (6.10 to 63.94 %) with increase additionof SF up to volume fraction percent of 1.5%.
4. The matrix steel fiber bond proved to be primed importance to strength of concrete composite.
5. The presence of reinforcing fiber has enhanced the matrix resistance.

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